Assessing Overwater Structure-related Predation on Juvenile Salmon: A Field Study and Protocol for Weighing the Evidence

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Abstract
Large overwater structures have often been cited as potential migratory barriers and areas of increased predation for juvenile salmon migrating along shallow shoreline habitats, although conclusive evidence has not been demonstrated to date in situ. To help resolve this issue, Washington State Ferries (WSF) sponsored directed research to determine whether WSF terminals affect predation on juvenile salmon. We used a combination of standardized surveys, stomach content analyses, and new observational technologies to assess fish, avian, and mammal predation on salmon fry at ferry terminals and paired reference sites during periods of pre- (early April) and peak (May) outmigration. We observed no significant aggregation of potential bird or mammal predators at six ferry terminal study sites. Few potential fish predators were documented in SCUBA surveys, beach seines, or with a Dual frequency IDentification SONar (DIDSON) camera at Mukilteo, our single underwater study location. Only one instance of salmon predation by fish (staghorn sculpin – *Leptocottus armatus*) was confirmed, and this was at the corresponding reference site. A tiered protocol (Minimum/ Recommended/ Preferred actions) was developed for assessing potential predation at other overwater structures. Likewise, recommendations were developed for incorporating design features into WSF terminal improvement projects that could minimize future impacts.

Extended Abstract

Introduction
Overwater structures represent a source of potential impact to estuarine and marine nearshore habitats, and engender a variety of environmental concerns. For example, overwater structures may increase predation on juvenile salmonids by aggregating fish, avian, and marine mammal predators or heightening the predation rates of predator species normally associated with these structures, although conclusive evidence has not been demonstrated to date *in situ* (Simenstad et al. 1999; Shreffler and Moursund 1999). The purpose of this study was to evaluate whether conditions associated with overwater structures enhance predation pressure on juvenile salmon in Puget Sound. Washington State Ferry (WSF) terminals served as a model overwater structure for exploring these issues.

Approach
This study reports bird and mammal survey results from six north-central Puget Sound WSF terminals and paired reference sites over peak periods of outmigrating salmon fry abundance from April 1 to May 10, 2002. Intensive survey methods at one site (Mukilteo) also involved SCUBA transects (benthic predatory fishes), snorkel transects (pelagic fishes), bird and marine mammal predator surveys, salmon fry abundance surveys; documentation of nearshore fish assemblages during all diel phases using boat-deployed beach seines; collection of live potential fish predators and the use of lavage techniques to pump stomach contents; documentation of light measurements; and the use of Dual-frequency Identification Sonar (DIDSON) to document potential predators associated with the water column and structurally complex terminal elements at night.

Summary Findings
Pink and chum salmon fry were present in shallow, nearshore habitats of most study sites throughout the duration of the project. An average of 5.7 (±13.7 SD) birds and mammals were seen per survey count; potential predator species made up about 30% of the individuals observed per count. Potential bird and mammal predators were observed more often than

expected at the ferry terminal sites. On average, 1.8 predators per survey count were observed at WSF terminal sites as compared with 1.27 predators at reference sites. Actual observations of bird or mammal predation on fish were rare, and on only one occasion was a predator (tern sp.) observed capturing juvenile salmon.

Salmon fry moved freely under the relatively narrow, shaded portion of the Mukilteo ferry terminal, where mean light levels during the day were reduced by over 97% in water. Juvenile pink and chum salmon dominated (>99%) seine catches at the Mukilteo location, and two Pacific staghorn sculpin (*Leptocottus armatus*) at the reference site were the only potential salmon predators collected with this method. SCUBA surveys documented higher total fish species diversity and average abundance at the Mukilteo ferry terminal than at the reference site, although only 11 observations (4 species: quillback rockfish, copper rockfish, lingcod, and staghorn sculpin) were made of potential salmon predator species. Most of the potential fish predator observations occurred in deeper habitats associated with the outer portion of the terminal (1.25 predators/survey). Transect surveys in shallower habitats <30 ft MLLW recorded few predators at either the terminal (0.09 predators/survey) or reference sites (0.21 predators/survey). DIDSON surveys at night also documented few instances in which large, water-column fish (potential salmon predators) were associated with ferry terminal structures. Stomach content analysis of 17 potential fish predators revealed salmon (two fry 50 mm and 55 mm FL) in the diet of one individual, a 170-mm staghorn sculpin captured in a beach seine at the reference site.

We conclude that potential salmon predators were slightly more abundant at WSF terminals as compared with unmodified shorelines, although large aggregations were not observed on any occasion. The spatial distribution patterns of both bird and fish predators rarely overlapped with juvenile salmon oriented in surface waters close to shore. We found no evidence that avian, marine mammal, or fish predators consumed more juvenile salmon near WSF terminals than along shorelines without overwater structures. Few species appeared to be targeting abundant fry in nearshore habitats, and we observed only two occasions where predators (one tern sp., one staghorn sculpin) had consumed juvenile salmon.

Several hypotheses are offered as to why rates of predation on juvenile salmon were not elevated in the face of their greater relative availability to predators in nearshore habitats. We recommend applying a standardized field protocol (see Appendix 1 in final report) to provide consistent procedures for evaluating predation risk to juvenile salmonids at existing overwater structures, especially as they are being expanded or modified. Use of these protocols over additional locations and situations will allow the scientific community to develop a stronger case for better evaluating this issue in the future.

The final report will be completed in June 2003 after further peer review and revisions. Electronic copies of the final report can be obtained via the web at http://www.wsdot.wa.gov/ppsc/research/reports.htm, or by contacting or by contacting the G. Williams at ph: (360) 681-3655, email: gregory.williams@pnl.gov.

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